İSTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF INFORMATICS

ANALYSIS OF A MONOPOLE ANTENNA WITH G TYPE STRUCTURE

M.Sc. Thesis by
Yasin Levent KURU

Department : **Communications Systems**

Programme : **Satellite Communication and Remote Sensing**

JULY 2010

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Yasin Levent KURU
(705061012)

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Supervisor (Chairman) : **Asist. Prof. Dr. Mesut KARTAL (ITU)**
Members of the Examining Committee : **Assoc. Prof. Dr. Seçuk PAKER(ITU)**
Assoc. Prof. Dr. Ali YAPAR(ITU)

JULY 2010

İSTANBUL TEKNİK ÜNİVERSİTESİ ★ BİLİŞİM ENSTİTÜSÜ

G TİP YAPIDAKİ MONOPOL ANTENİN ANALİZİ

YÜKSEK LİSANS TEZİ

Yasin Levent KURU
(705061012)

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Diğer Jüri Üyeleri : Doç. Dr. Seçuk PAKER(ITU)
Doç. Dr. Ali YAPAR(ITU)

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FOREWORD

First; Prof. İbrahim Akduman, who give me chance to studying master program of Satellite Communication even notice that im an industrial engineer, to my supervisor Assist. Prof. Dr. Mesut Kartal showed my way on my thesis and tolerate my last time activities, to Assist. Prof Yasemin Altuncu who teach me electromagnetic waves with patient and to my family; supports me everwhere and everytime.

Thank You

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ABBREVIATIONS

HFSS **:** High Frequency Structure Similator
IEEE **:** The Institute of Electrical and Electronics Engineers
PEC **:** Perfect Electric Conductor
RLC **:** Resistor Indictor Capacitor
U-NII **:** Unlicensed National Information Infrastructure
UWB **:** Ultra Wide Band
VSWR **:** Voltage Standing Wave Ratio
HPBW **:** Half Power Beamwidth

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ANALYSIS OF A MONOPOLE ANTENNA WITH G TYPE STRUCTURE

SUMMARY

In this study, analyzing parameters of a monopole antenna with G type structure is proposed consisting of one closed rectangular wire loop and one open rectangular wire loop, fed by 50Ω coaxial cable. Parameters are; closed rectangular wire radius, open rectangular wire radius, length of wire respect to the frequency, length L1 and angles of corners. The software Ansoft HFSS is used to analyze parameters of antenna for gain, bandwith and radiation pattern. Parameters are tested for two central frequency; 1.1 GHz and 5 GHz.

Results shows proposed antenna radiates at 1.1 GHz and 5 GHz with VSWR less than 2 and antenna has % 60 bandwith without changing basic structure.

Last of all ; antenna arrays analyzed for proposed antenna with 2 dimension planar structure.Half wavelength distance between elements gives acceptable results for many applications.

G-TİP MONOPOL ANTENİN ANALİZİ

ÖZET

Bu tezde G-Tip yapıda olan monopol antenin parametreleri analiz edilmilştir.

Anten bir kapalı uçlu kare tel döngüsü ve açık uçlu kare tel döngüsü ile oluşturulmuş, 50Ω' luk koaksiyel kablo ile beslenmiştir.

Analiz edilen parametreler; kapalı uçlu kare tel döngüsünün tel kalınlık yarıçapı, açık uçlu kare tel döngüsünün tel kalınlık çapı, frekansa göre tel uzunluğu, L1'in ölçüsü ve antenin köşe açılarıdır. Bu parametreler Ansoft HFSS yazılımı kullanılarak antenin kazanç, bant genişliği ve ışıma diyagramı açısından analiz edilmiştir. Parametreler 1.1 GHz ve 5 GHz merkez frekansları için analiz edilmilştir.

Sonuçlar göstermektedir ki önerilen anten 1.1 GHz ve 5 GHz de VSWR değeri 2 nin altında ışıma yapmakta, temel anten yapısı değiştirilmeden %60 bant genişiliğini sağlamaktadır.

Son olarak sunulan anten için 2 boyutlu düzlemsel diziler incelenmiştir. Dizi bileşenleri arası uzaklık yarım dalga boyu seçildiğinde dizinin verdiği sonuçlar birçok uygulama için kabul edilebilir durumdadır.

1. INTRODUCTION

In recent years wireless communication becomes popular and important. Monopole antennas are often used for a lot of wireless applications because of UWB, omni pattern, compact size and stable gain. Top loaded monopole [1,2] folded monopole [3,4] RLC loaded monopole [5] methods realizes wideband.

A lot of standarts and applications are devepoled in wireless communication. With these developments different operation frequencies and bandwiths are start to use.

5 GHz U-NII band is start to using in recent years. Most famous protocol is IEEE 802.11.a and using band 5.150–5.350/5.725–5.825 GHz.

In this study, analyzing parameters of a monopole antenna with G type structure and a prototype antenna is proposed.

1.1 What Is An Antenna

An antenna is defined as a usually metallic device for radiating or receiving radio waves IEEE defines the antenna as a means for radiating or receiving radio waves. In other words the antenna is the transitional structure between free-space and a guiding device. The guiding device or transmission line may take the form of a coaxial line or a hollow pipe (waveguide), and it is used to transport electromagnetic energy from the transmitting source to the antenna, or from the antenna to the receiver. Today so many antenna types using for communication. Popular antenna types described below[6].

1.2 Types Of Antennas

1.2.1 Wire antennas

Wire antennas are familiar to the layman because they are seen everywhere on automobiles, buildings, ships, aircraft, spacecraft, and so on. There are various shapes of wire antennas such as a straight wire (dipole), loop, and helix.

They may take the form of a rectangle, square, ellipse, or any other configuration. The circular loop is the most common because of its simplicity in construction.

1.2.2 Aperture antennas

Aperture antennas may be more familiar to the layman today than in the past because of the increasing demand for more sophisticated forms of antennas and the utilization of higher frequencies. Antennas of this type are very useful for aircraft and spacecraft applications, because they can be very conveniently flush-mounted on the skin of the aircraft or spacecraft. In addition, they can be covered with a dielectric material to protect them from hazardous conditions of the environment.

1.2.3 Microstrip antennas

Microstrip antennas became very popular in the 1970s primarily for spaceborne applications. Today they are used for government and commercial applications. These antennas consist of a metallic patch on a grounded substrate. The metallic patch can take many different configurations. However, the rectangular and circular patches, are the most popular because of ease of analysis and fabrication, and their attractive radiation characteristics. The microstrip antennas are low profile, comformable to planar and nonplanar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces and very versatile in terms of resonant frequency, polarization, pattern, and impedance. These antennas can be mounted on the surface of high-performance aircraft, spacecraft, satellites, missiles, cars, and even handheld mobile telephones.

1.2.4 Reflector antennas

The success in the exploration of outer space has resulted in the advancement of antenna theory. Because of the need to communicate over great distances, sophisticated forms of antennas had to be used in order to transmit and receive signals that had to travel millions of miles. A very common antenna form for such an application is a parabolic reflector. Antennas of this type have been built with diameters as large as 305 m. Such large dimensions are needed to achieve the high gain required to transmit or receive signals after millions of miles of travel.When select to use an antenna type, usage purpose is so important.

For example long distance communication better to use an directive antenna. Directivity is just a parameter of antenna. And now parameters of antenna on the stage.

1.3 Parameters Of Antenna

To describe the performance of an antenna, definitions of various parameters are necessary. Some of the parameters are interrelated and not all of them need be specified for complete description of the antenna performance. Many of those parameters are from the IEEE Standard Definitions of Terms for Antennas (IEEE Std 145-1983). Describing parameters are; radiation pattern, directivity, antenna efficency, gain and bandwidth.

1.3.1 Radiation pattern

An antenna radiation pattern or antenna pattern is defined as a mathematical functionor a graphical representation of the radiation properties of the antenna as a function of space coordinates. Inmost cases, the radiation pattern is determined in the farfield region and is represented as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization. The radiation property of most concern is the two or three dimensional spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius. A trace of the received electric (magnetic) field at a constant radius is called the amplitude field pattern. On the other hand, a graph of the spatial variation of the power density along a constant radius is called an amplitude power pattern.

Often the field and power patterns are normalized with respect to their maximum value, yielding normalized field and power patterns. Also, the power pattern is usually plotted on a logarithmic scale or more commonly indecibels (dB). This scale is usually desirable because a logarithmic scale can accentuate in more details those parts of the pattern that have very low values, which later we will refer to as minor lobes.

1.3.2 Directivity

In the 1983 versionof the IEEE Standard Definitions of Terms for Antennas, there has been a substantive change in the definition of directivity, compared to the definition of the 1973 version. Basically the term directivity inthe new 1983 version has been used to replace the term directive gain of the old 1973 version. In the new 1983 version the term directive gain has beendeprecated. According to the authors of the new 1983 standards, this change brings this standard in line with common usage among antenna engineers and with other international standards, notably those of the International Electrotechnical Commission (IEC). Therefore directivity of an antenna defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation intensity is implied. Stated more simply, the directivity of a nonisotropic source is equal to the ratio of its radiation intensity in a given direction over that of an isotropic source. In mathematical form;

$$D = \frac{4\pi U}{P_{rad}} \quad \textbf{(1.1)}$$

D = directivity (dimensionless)
U = radiation intensity (W/unit solid angle)
Prad = total radiated power (W)

1.3.3 Antenna efficency

Associated with an antenna are a number of efficiencies. The total antenna efficiency e0 is used to take into account losses at the input terminals and within the structure of the antenna. Such losses ;

1. reflections because of the mismatch between the transmission line and the antenna
2. I^2R losses (conduction and dielectric)

In general, the overall efficiency can be written as

e0=er*ec*ed **(1.2)**

e0 = total efficiency

ec : conduction efficiency

ed : dielectric efficiency

er : reflection(mismatch) efficiency = $(1-|\Gamma|^2)$ **(1.3)**

$|\Gamma|$ = voltage reflection coefficient at the input terminals of the antenna

$|\Gamma|$ = (Zin − Z0)/(Zin + Z0) where Zin = antenna input impedance,

Z0 = characteristic impedance of the transmission line

VSWR = voltage standing wave ratio = $\frac{1+|\Gamma|}{1-|\Gamma|}$ **(1.4)**

1.3.4 Gain

Another useful measure describing the performance of an antenna is the gain. Although the gain of the antenna is closely related to the directivity, it is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. Remember that directivity is a measure that describes only the directional properties of the antenna, and it is therefore controlled only by the pattern. Gain of an antenna (in a given direction) is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically.

The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π. Inequation form this can be expressed as

$$Gain = 4\pi \frac{\text{radiation intensity}}{\text{total input (accepted) power}} = 4\pi \frac{\mathrm{U}(\theta,\phi)}{\mathrm{P_{in}}}$$ **(1.5)**

1.3.5 Bandwidth

The bandwidth of an antenna is defined as the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard. The bandwidth can be considered to be the range of frequencies, on either side of a center frequency (usually the resonance frequency for a dipole), where the antenna characteristics (such as input impedance, pattern, gain,direction) are within an acceptable value of those at the center frequency.

For broadband antennas, the bandwidth is usually expressed as the ratio of the upper-to-lower frequencies of acceptable operation. For example, a 10:1 bandwidth indicates that the upper frequency is 10 times greater than the lower. For narrowband antennas, the bandwidth is expressed as a percentage of the frequency difference (upper minus lower) over the center frequency of the bandwidth.

For example, a 5% bandwidth indicates that the frequency difference of acceptable operation is 5% of the center frequency of the bandwidth. Because the characteristics (input impedance, pattern, gain) of an antenna do not necessarily vary in the same manner or are even critically affected by the frequency, there is no unique characterization of the bandwidth. The specifications are set in each case to meet the needs of the particular application.

1.4 Design Tool

In this work before realize the antenna, a computer simulation program used for analyze. These simulation programs called electromagnetic (EM) simulators. Electromagnetic (EM) simulators are fundamentally computer software tools that are used for microwave analysis, design, and optimization. Their existence has provided RF and high-speed digital designers with the resources needed to confront very difficult design problems. The primary objective of an EM simulator is to analyze electromagnetic fields.

Field solvers apply this capability in applications like antennas, active devices, electromagnetic interference (EMI), and RF and microwave circuits. There is so much simulators on the market. In this work Ansoft HFSS used. HFSS is a high performance full-wave electromagnetic(EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy-to-learn environment where solutions to your 3D EM problems are quickly and accurately obtained. Ansoft HFSS employs the Finite Element Method(FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as SParameters, Resonant Frequency, and Fields. Typical uses include: Package Modeling – BGA, QFP, Flip-Chip PCB Board Modeling – Power/Ground planes, Mesh Grid Grounds, Backplanes Silicon/GaAs -

Spiral Inductors, Transformers EMC/EMI – Shield Enclosures, Coupling, Near- or Far-Field Radiation, Antennas/Mobile Communications, Patches, Dipoles, Horns, Conformal Cell Phone Antennas, Quadrafilar Helix, Specific Absorption Rate(SAR), Infinite Arrays, Radar Cross Section(RCS), Frequency Selective Surfaces(FSS) Connectors – Coax, SFP/XFP, Backplane, Transitions Waveguide – Filters, Resonators, Transitions, Couplers Filters – Cavity Filters, Microstrip, Dielectric

HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes, in a fraction of the time it would take using other techniques. The name HFSS stands for High Frequency Structure Simulator. Ansoft pioneered the use of the Finite Element Method(FEM) for EM simulation by developing/implementing technologies such as tangential vector finite elements, adaptive meshing, and Adaptive Lanczos-Pade Sweep(ALPS). Today, HFSS continues to lead the industry with innovations such as Modes-to-Nodes and Full-Wave Spice™.

Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, Ansoft HFSS is the tool of choice for high-productivity research, development, and virtual prototyping[7].

Ansoft HFSS used for analyze antenna parameters. Analyzed parameters are closed rectangular wire radius, open rectangular wire radius, length of wire respect to the frequency, length L1 and angles of corners. These parameters are analyzed for performance criterias as gain, bandwith and radiation. After analyze and optimisation procedures proposed antenna has omni pattern and near 5dB gain for 5 GHz band. The following will give full details of the proposed antenna design.

2. ANTENNA STRUCTURE

The configuration of the proposed antenna is shown in Figure 2.1[8]. Proposed antenna consists one closed rectangular wire loop and one open rectangular wire loop. Antenna is mounted on a finite perfect electric conductor (PEC) ground plane. Two rectangle rings bottom points are on the same line. This makes proposed monopole antenna is a G shape antenna.

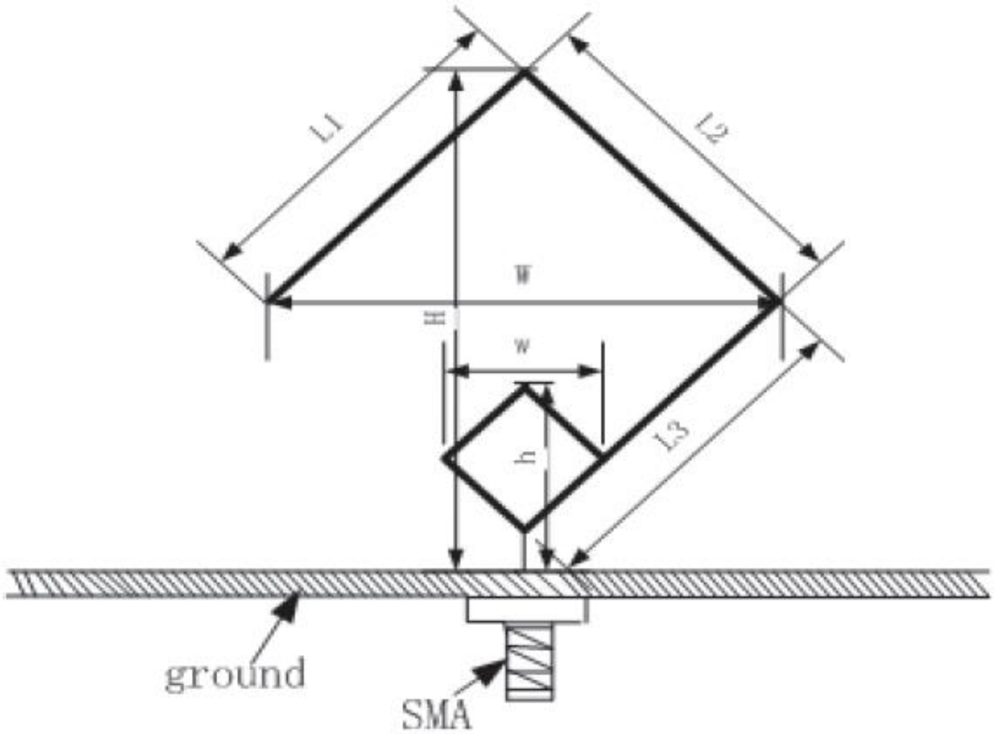

Figure 2.1 : The wideband monopole with G type structure

The initial dimensions of the proposed structure are chosen as; height of antenna H = 11 cm, diagonal line of bigger rectangle W = 11 cm. The bigger rectangle has dimensions L1 = 7 cm , L2 = L3 = 7.5 cm.

Initial central frequncy is 1.1 GHz and L2, L3 are respect to around 0.25 λ, w is small rectangle diagonal length and w = 5 cm, h is small rings height and h = 5.5 cm.

Antenna bottom point, small rectangle top point, and bigger rectangle top point are on the same line and this line is perpendicular to the ground plane. Initial wire radius of antenna is 2 mm.

The proposed monopole antenna is fed at the bottom point through SMA connector with 50 Ω coaxial cable line as shown in Figure 2.1.

In this work, the proposed model is designed by using Ansoft HFSS and is analyzed by antenna wire radius, small rectangle radius,dimensions respect to the frequency ,length L1 and angle of corners. Following will give details of analyze results. Figure 2.2 shows antenna model on HFSS.

Next analyze step is radius.Radius is key the element on input impedance of monopole antennas.

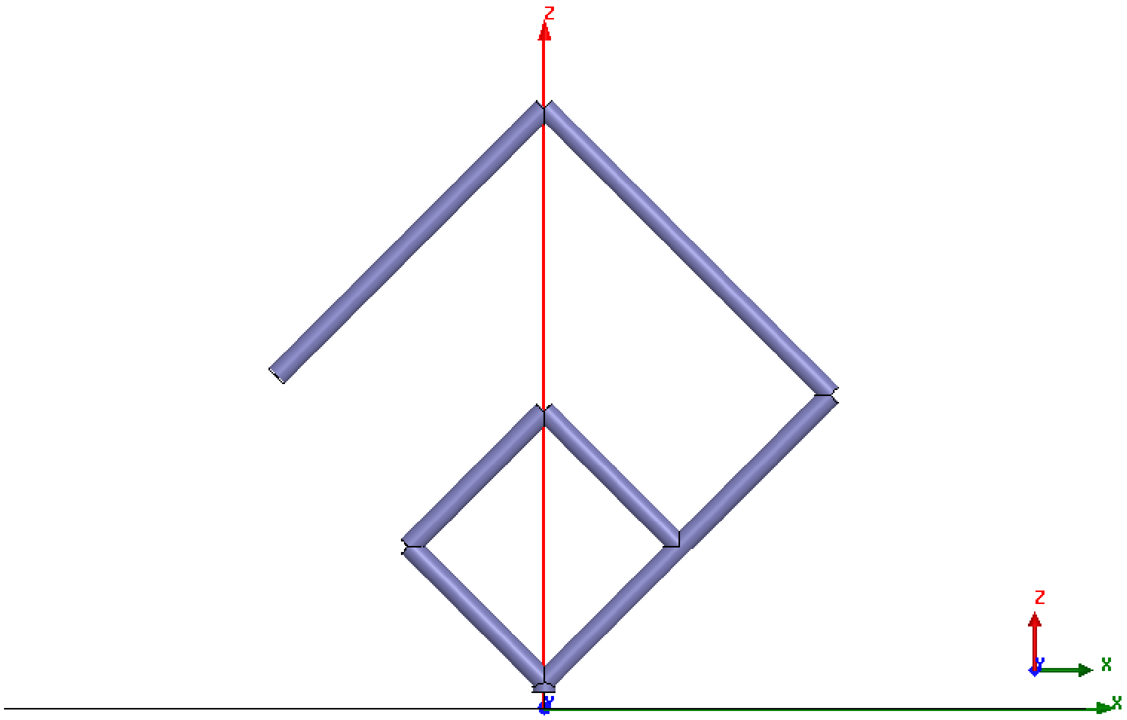

Figure 2.2 : Monopole with G type structure designed with HFSS

3. ANALYZING RADIUS

3.1 Complete Structure Radius

On the dipole and monopole antennas, radius is very effective on input impedance and input impedance determines the bandwidth. The fatter(larger radius) the dipole, the broader the bandwith. Monopole antenna's impedance is half of the dipole one [9].

For the first step of the analysis, complete structure is analyzed with the antenna radius from 1mm to 6mm. Height of antenna is H = 11 cm, diagonal line of bigger rectangle is W = 11 cm. The bigger rectangle has dimensions L1 = 7 cm, L2 = L3 = 7.5 cm. The analyzed is realized with two operating frequencies. These are 1.1 GHz and 5 GHz.

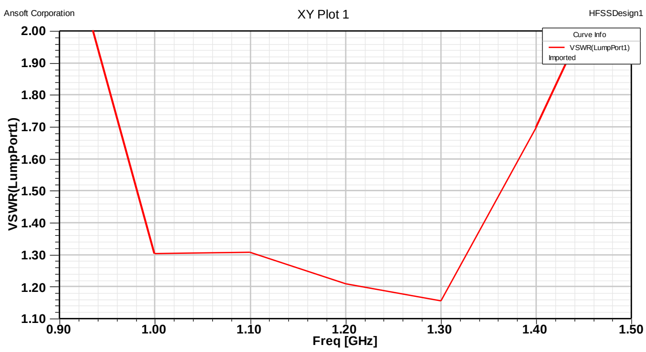

Figure 3.1 : VSWR with 2 mm radius, frequency 1.1 GHz.

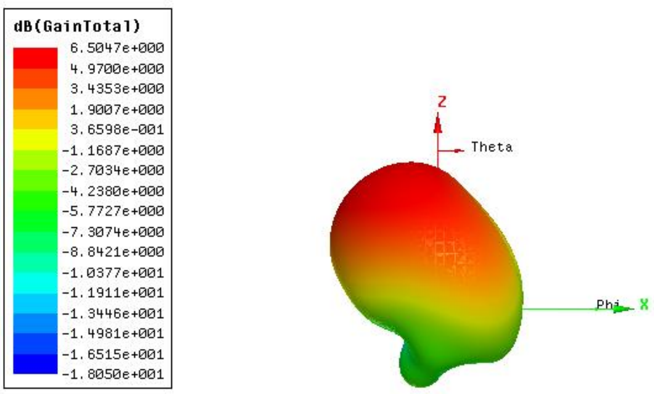

Figure 3.2 : 3D pattern with 2 mm radius, frequency 1.1 GHz.

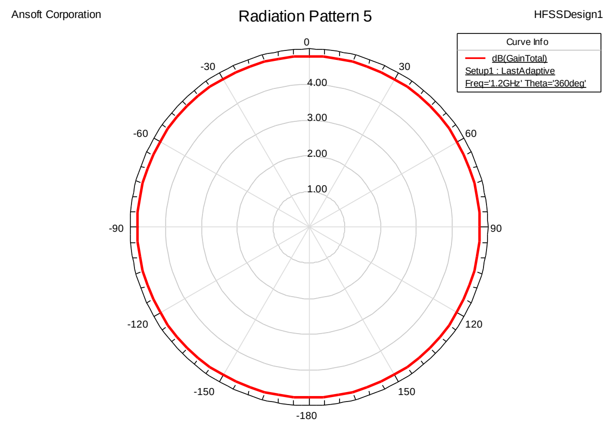

Figure 3.3 : Radiation pattern, 2 mm radius, frequency 1.1 GHz.Theta = 360˚

Figure 3.2 shows the designed antenna has a total gain = 6.5 dB, bandwidth = 500 MHz between 0.95 GHz and 1.45 GHz with WSVR < 2, operating frequncy 1.1 GHz. Figure 3.3 shows proposed antenna has omni characteristics at Theta = 360˚. For the second operating frequency (5 GHz), the results are as follows:

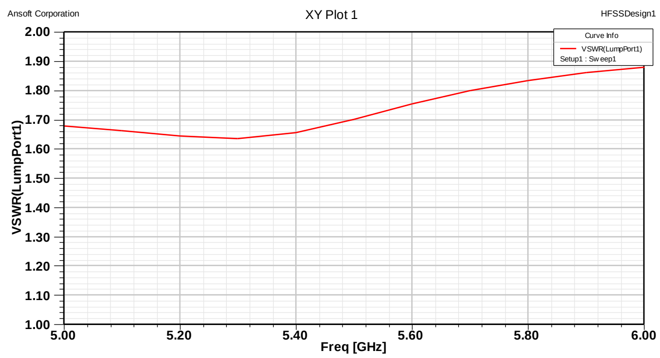

Figure 3.4 : VSWR with 2 mm radius ,frequency 5 GHz**.**

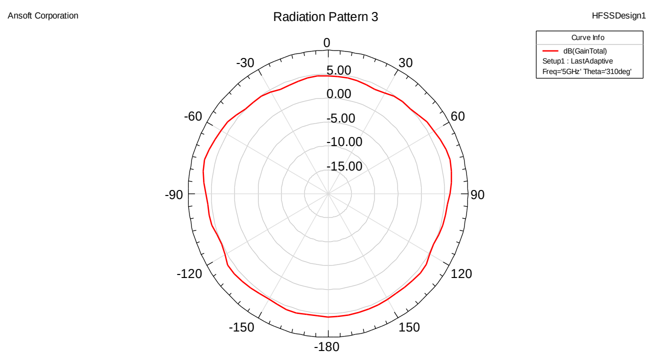

Figure 3.5 : Radiation pattern with 2 mm radius ,frequency 5 GHz, Theta = 310˚

As seen from Figures 3.3, 3.4 and 3.5; analyzes proves that the radius parameter effects generally on the bandwith while radiation pattern keeps omni characteristics.

To analyze the radius parameter effect on the VSWR and bandwidth, another application result is given in Figures 3.6 to 3.9. The results are obtained by the radius parameter as 1 mm , 4 mm, 6 mm and operating frequency are 1.1 GHz and 5 GHz.

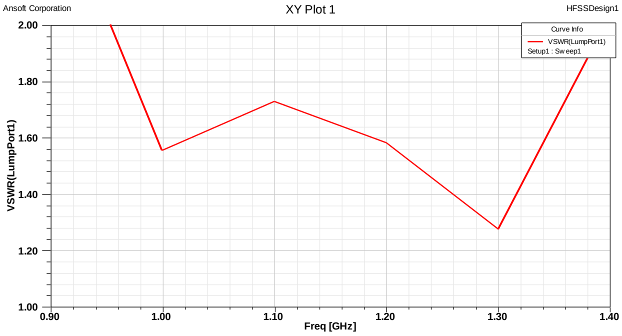

Figure 3.6 : VSWR with 1 mm radius ,frequency = 1.1 GHz.

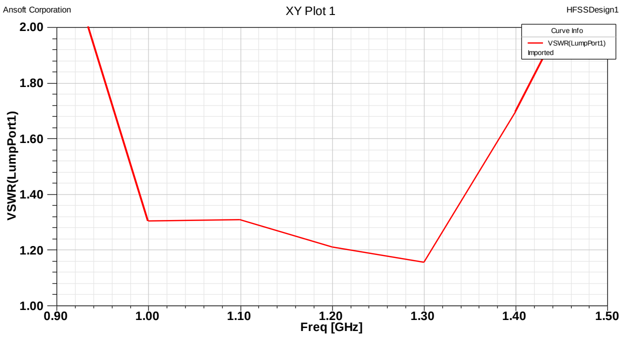

Figure 3.7 : VSWR with 4 mm radius, frequency = 1.1 GHz.

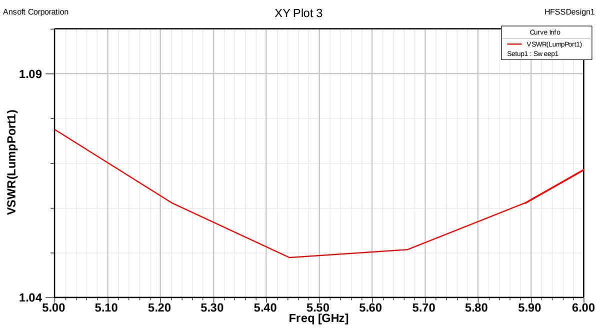

Figure 3.8 : VSWR with 4 mm radius, frequency = 5 GHz.

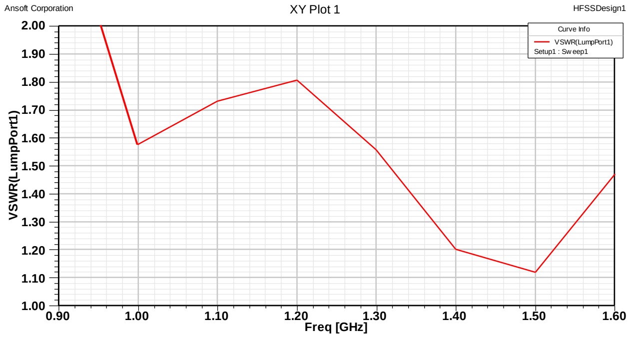

Figure 3.9 : VSWR with 6 mm radius, frequency = 1.1 GHz.

As seen from Figures 3.8 and 3.9, the radius sellection of 4 mm gives the best results both for 1.1 GHz and 5 GHz. For 5 GHz, antenna bandwith is more than 1 GHz and can radiate between 5 GHz – 6 GHz. From the results one can say that the designed antenna satisfies the desireed bandwithh criteria. For the second step, the radiuses of small and big rectangles are chosen seperately. Two cases are:

3.2 Big Rectangle With 2 mm Radius, Small Rectangle With 4 mm Radius

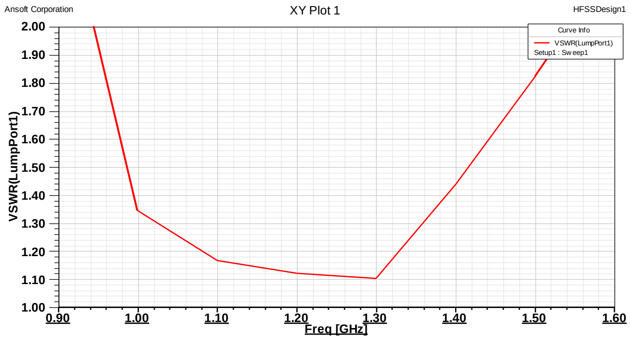

Figure 3.10 : VSWR big rectangle with 2 mm radius, small rectangle with 4 mm radius, frequency 1.1 GHz.

3.3 Big Rectangle With 4 mm Radius, Small Rectangle With 1 mm Radius

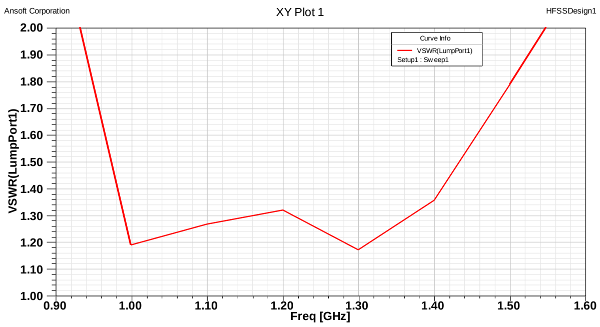

Figure 3.11 : VSWR big rectangle with 4 mm radius, small rectangle with 1 mm radius, frequency 1.1 GHz.

Previus studies show the effect of the small rectangle's (square ring) parameters on the G type antenna design. The input impedence of the main antenna including the small rectangle is about 50 Ω. The input impedance is near 200 Ω without small rectangle [8].

Analyzes proves that input impedance is effected by the small rectangle radius. However the results show that the previous antenna structure (all structure has the same radius of 4 mm) gives better results for 5 GHz frequency by comparing the Figure 3.8 and Figure 3.12. But for 1 Ghz case is not same as seen in Figure 3.10 and 3.11. Big rectangle with 2 mm radius, small rectangle with 4 mm radius gives better result than 4 mm all structure radius. Seen from Figure 3.10 bandwith is 100 Mhz more.

Next step of analyze is monoploe length. Length has relation with current distribution and its worth to analyze.

4. ANALYZING MONOPOLE LENGTH

For antenna analysis and design it is all about the current distribution.[9] Length of monopole antenna determines current distribution. Finally antenna parameters depends to length of monopole antenna.

For length of wire(L), most common used wavelength for monopole antennas are choosed; 0.05 λ, 0.25 λ, 0.5 λ, 0.75 λ and for multiple resonance 1 λ, 2 λ are choosed. Simulation proves for 1.1 GHz selecting length of wire for 0.25 λ provides 800 Mhz bandwith and for 5 GHz 1 λ provides more than 1 GHz and VSWR less than 1.1 as seen in Figure 4.5.

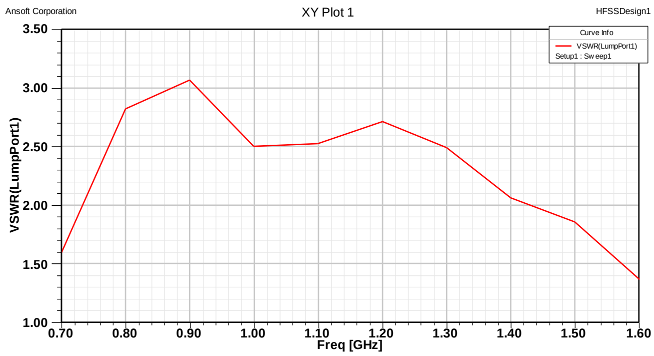

Figure 4.1 : VSWR , 0.5 λ , frequency 1.1 GHz, radius = 4 mm.

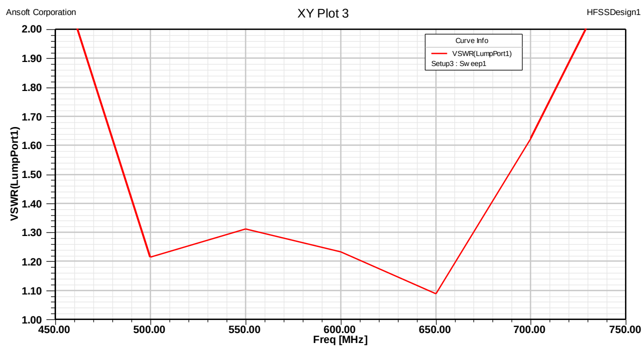

Figure 4.2 : VSWR 0.25 λ, frequency 600 Mhz, radius = 4 mm.

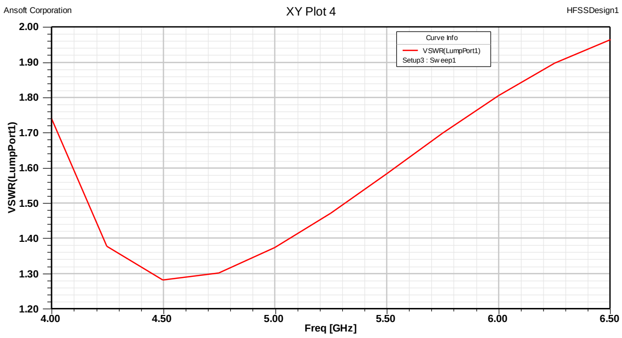

Figure 4.3 : VSWR , 0.25 λ , frequency 5 GHz, radius = 4 mm.

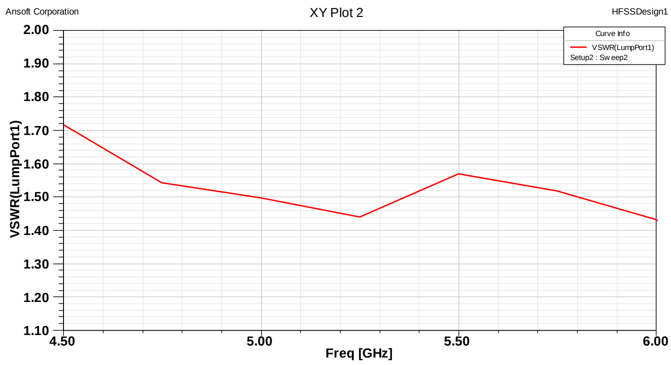

Figure 4.4 : VSWR, 0.5 λ, frequency 5 GHz, radius = 4 mm.

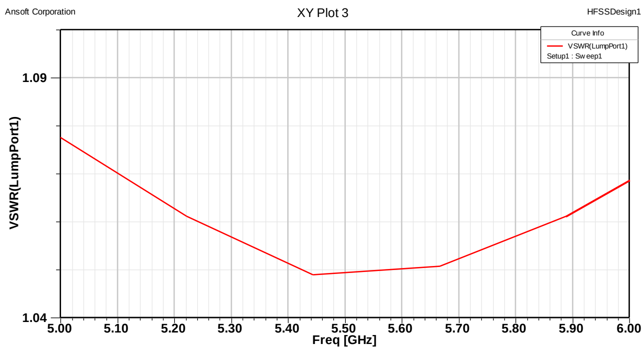

Figure 4.5 : VSWR, 1 λ, frequency 5 GHz, radius = 4 mm.

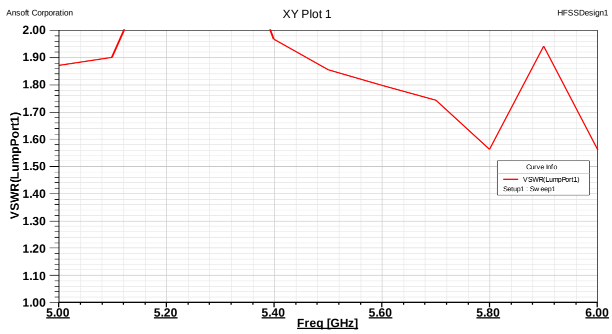

Figure 4.6 : VSWR, 2 λ, frequency 5 GHz, radius = 4 mm

In Figure 4.1 and 4.6 VSWR has value bigger than 2 and these lengths are not acceptable. Figure 4.2 shows antenna acts near same below 1 GHz. VSWR values are similar just frequncy value is half of 1.2 GHz.

For 5 Ghz. 0.25 λ, 0.5 λ, and 1 λ can use as length of monopole. As seen from Figure 4.3 to 4.5 VSWR values are under 2. In this situation antenna volume is the key. 0.25 λ is 1.5 cm. and 1 λ is 6 cm. for 5 GHz. In design stage designer have to choose for length.

5. ANALYZING DIMENSION OF L1

Monopoles are loaded with active (transistor, tunnel diode, varactor, etc.) and passive (inductor, capacitor, resistance or combinations) elements. The load is used to increase the radiation resistance, the effective bandwidth and to modify the radiation pattern of the linear monopole. The performance of the monopole changes according to the position of the load on the antenna's conductor[10].

In proposed antenna, L1 acts as a loading element, tuning out reactive components of the impedance and length L1 effects on bandwith[9].

For analyze the effect, in HFSS model antenna structure is same with first initial structure, radius is 4 mm and L1 selected 5 cm, 9 cm, 11 cm for analyze. Results of analyzes are following :

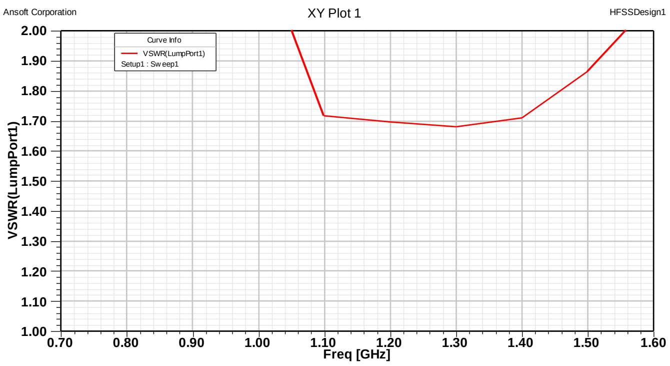

Figure 5.1 : VSWR, frequency 1.1 GHz, L1 = 5 cm.

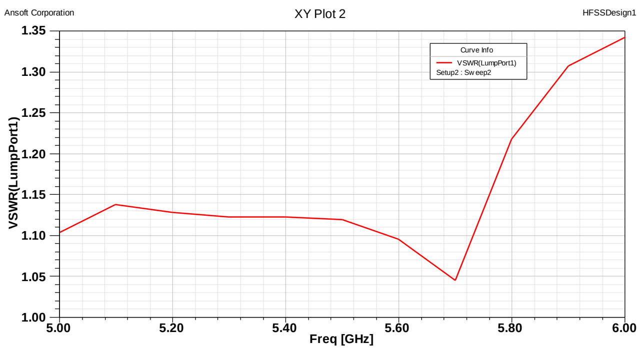

Figure 5.2 : VSWR, frequency 5 GHz, L1 = 5 cm.

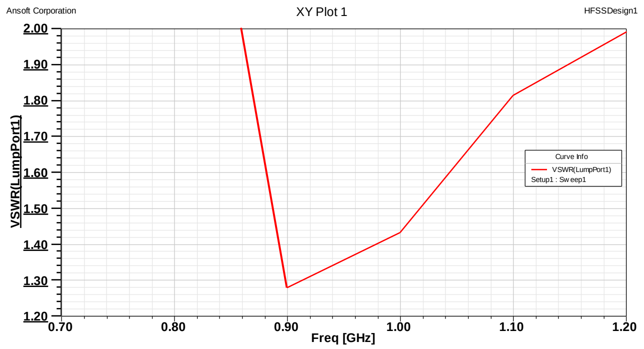

Figure 5.3 : VSWR, frequency 1 GHz, L1 = 9 cm.

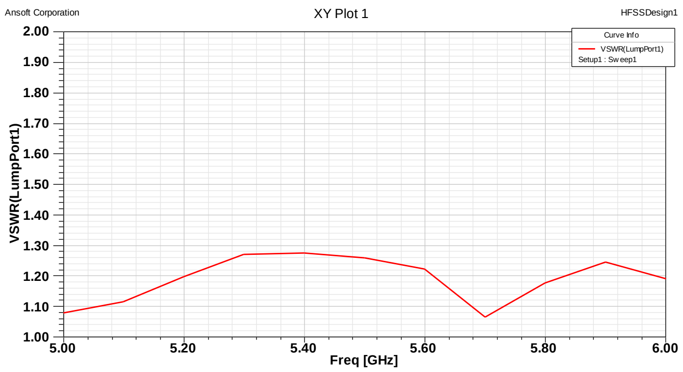

Figure 5.4 : VSWR, frequency 5 GHz, L1 = 9 cm.

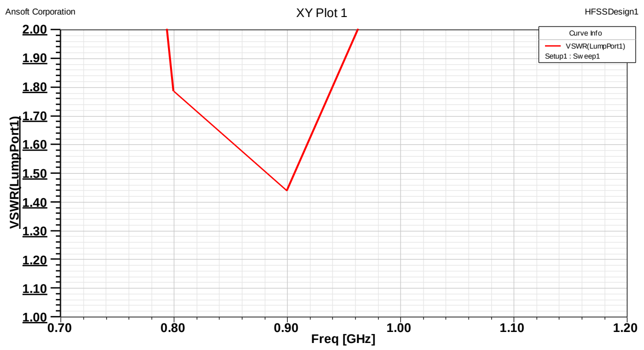

Figure 5.5 : VSWR, frequency 1.1 GHz, L1 = 11 cm.

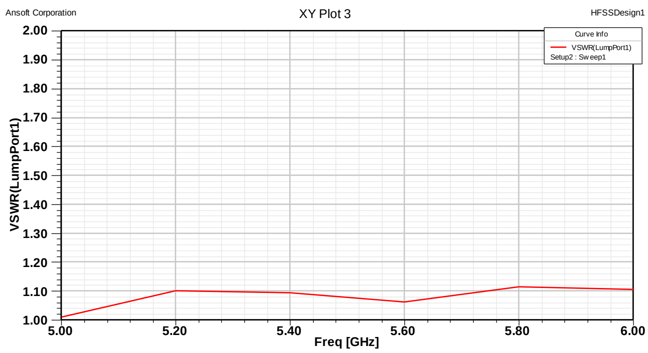

Figure 5.6 : VSWR, frequency 5 GHz, L1 = 11 cm

As seen from Figure 5.1 to Figure 5.5 changing L1 is not effecting good way.

Just for 5 GHz if L = 11 cm, VSWR value is 1.02 and better than L = 7 cm as in Figure 5.6.

Another analyze parameter of antenna is angles of corners.Initial antenna angle is 90˚, for analyzing coupling effect angles of corners has to be analyzed.

6. ANALYZING ANGLES

Angle is last analyze parameter of proposed antenna. Initial angle is 90˚ for every corner. Main rule for changing angles is bottom and upper points are on the same line and perpendicular to the ground. As shown in the figures two model analyzed; 120˚ and 60˚ .VSWR and radiation pattern results given in following.

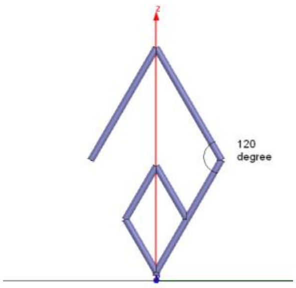

Figure 6.1 : The wideband monopole with G type structure angle 120˚ deg

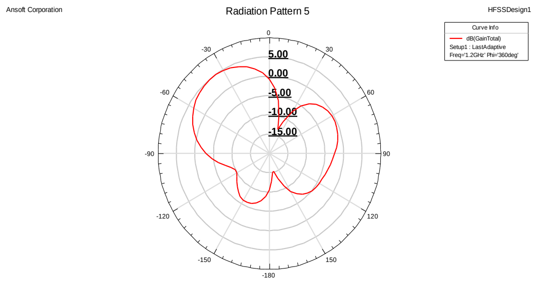

Figure 6.2 : Radiation pattern angle 120˚, frequency 1.1 GHz Phi 360˚

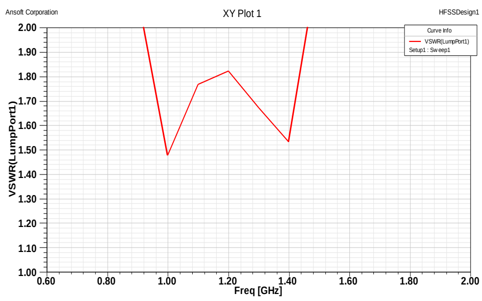

Figure 6.3 : VSWR, frequency 1.1 GHz, angle 120˚

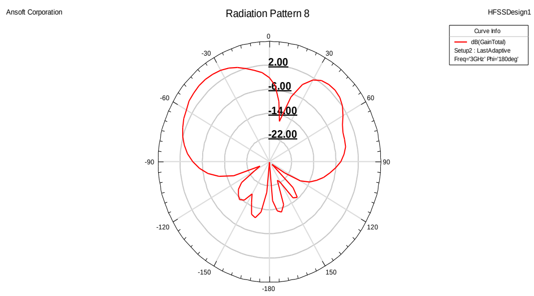

Figure 6.4 : Radiation pattern, angle 120˚ , frequency 1.1 GHz Phi 180˚

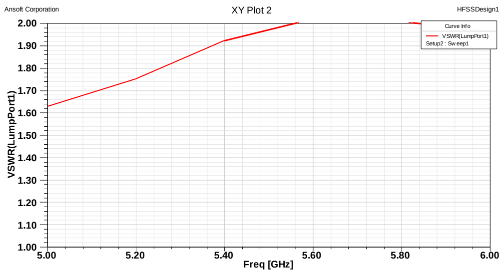

Figure 6.5 : VSWR, frequency 5 GHz, angle 120˚

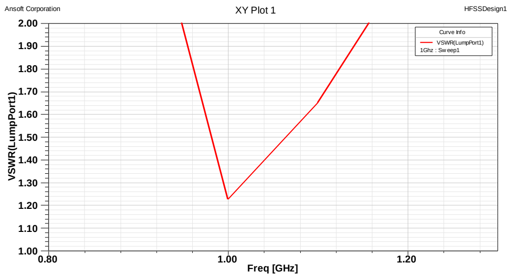

Figure 6.8 : VSWR, frequency 1.1 GHz, angle 60˚

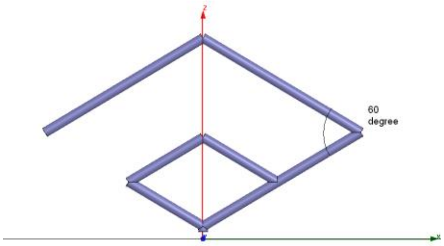

Figure 6.6 : The wideband monopole with G type structure angle = 60˚ deg.

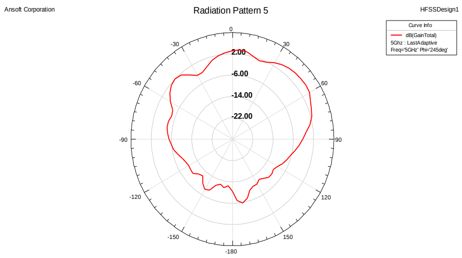

Figure 6.9 : Radiation pattern angle 60˚, frequency 5 GHz, Phi 245˚

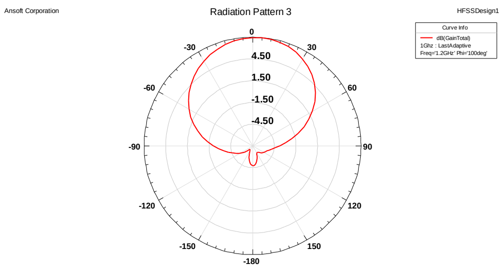

Figure 6.7 : Radiation pattern angle 60˚, frequency 1.1 GHz. Phi 100˚ deg.

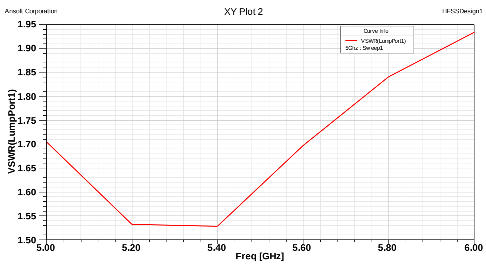

Figure 6.10 : VSWR, frequency 5 GHz, angle 60˚

As seen from Figure 6.2; angle = 120 ˚, maximum radiation at - 45˚ for both frequencies and its directional. Directional pattern can be selectable for some applications but VSWR response shows that antenna performance is not good as original structure as seen in Figure 6.3 and Figure 6.5. For angle = 60 ˚ , maximum radiation at 0˚ and very good directional pattern can seen for 1.1 GHz as shown in Figure 6.7. VSWR response shows antenna has narrow bandwith about 200 MHz between 950 MHz – 1150 MHz as seen in Figure 6.8.

Explanation for changing in pattern and bandwith only with angle; measure between antenna elements changed (L1,L2,L3) and thats cause to coupling effect.

Making angle different than 90˚, close ups elements and makes more parallel to each other and the parallel configuration couples more than the collinear configuration[9].

Chapters 2 to 6 are about analyzing antenna structure.After that part antrenna array configurations will be discussed.

7. ANALYZING ARRAYS

Usually the radiation pattern of a single element is relatively wide, and each element provides low values of directivity (gain). In many applications it is necessary to design antennas with very directive characteristics (very high gains) to meet the demands of long distance communication. This can only be accomplished by increasing the electrical size of the antenna.

Enlarging the dimensions of single elements often leads to more directive characteristics.

Another way to enlarge the dimensions of the antenna, without necessarily increasing the size of the individual elements, is to form an assembly of radiating elements in an electrical and geometrical configuration. This new antenna, formed by multielements, is referred to as an array. In most cases, the elements of an array are identical. This is not necessary, but it is often convenient, simpler, and more practical.

The individual elements of an array may be of any form (wires, apertures, etc.).

The total field of the array is determined by the vector addition of the fields radiated by the individual elements. This assumes that the current in each element is the same as that of the isolated element. This is usually not the case and depends on the separation between the elements.

To provide very directive patterns, it is necessary that the fields from the elements of the array interfere constructively (add) in the desired directions and interfere destructively (cancel each other) in the remaining space. Ideally this can be accomplished, but practically it is only approached. In an array of identical elements, there are at least five controls that can be used to shape the overall pattern of the antenna. These are:

- the geometrical configuration of the overall array (linear, circular, rectangular, spherical, etc.)
- the relative displacement between the elements
- the excitation amplitude of the individual elements

- the excitation phase of the individual elements
- the relative pattern of the individual elements

There are a plethora of antenna arrays used for personal, commercial, and military applications utilizing different elements including dipoles, loops, apertures, microstrips, horns, reflectors, and so on. Example for an array is widely used as a base-station antenna for mobile communication. A triangular array consisting of twelve dipoles, with four dipoles on each side of the triangle. Each four-element array, on each side of the triangle, is basically used to cover an angular sector of 120° forming what is usually referred to as a sectoral array. Another example is a classic array of dipoles, referred to as the Yagi-Uda array, and it is primarily used for TV and amateur radio applications.

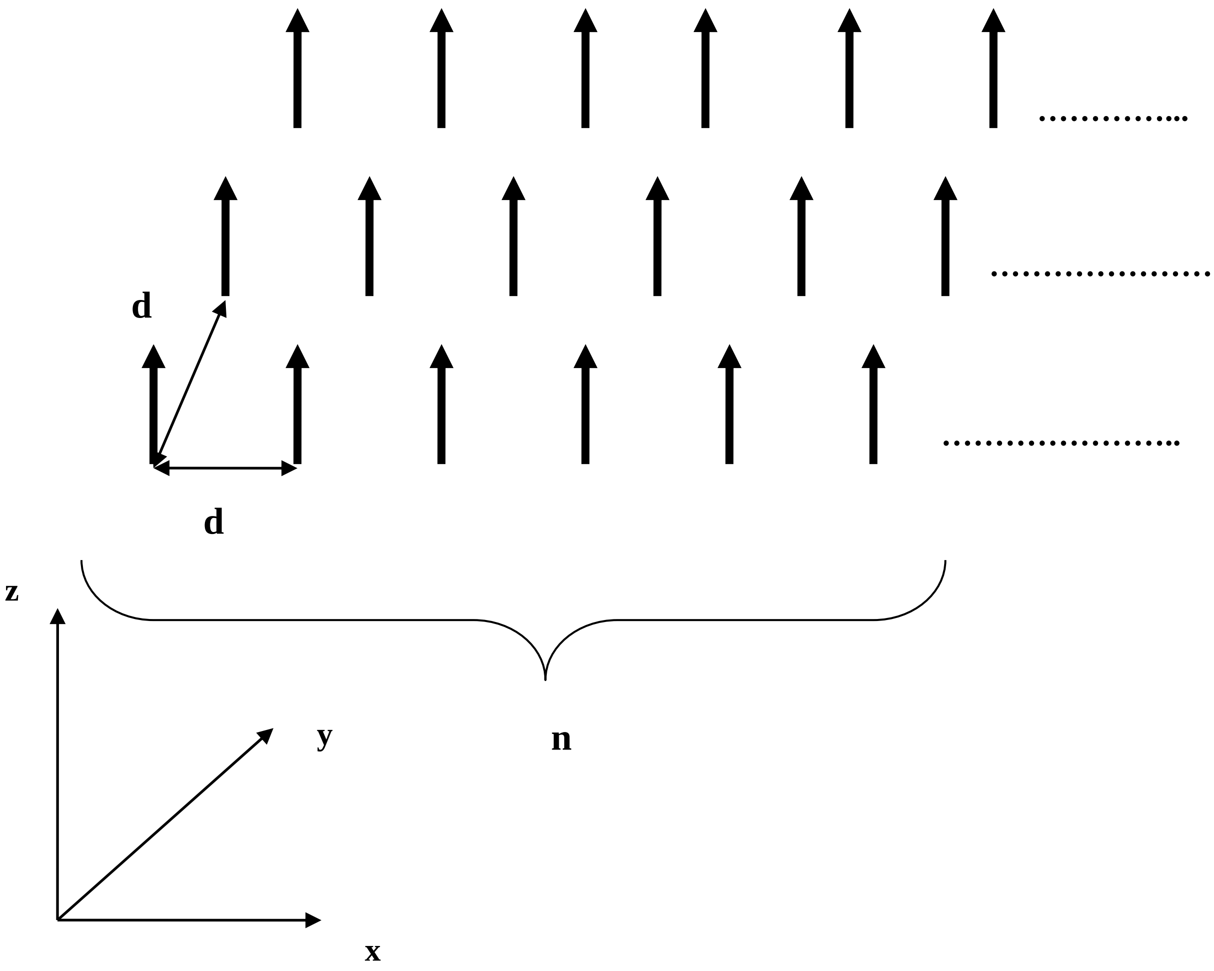

Figure 7.1 : Antenna Array Space

In Figure 7.1 arrows represents single antenna elements on a planar surface,
d is distance between single antenna elements.
n is the number of single antenna elements.For example 3x3 array means 9 single antenna elements.
In this work for array analysis 1 GHz and 5 GHz are selected frequencies. Antenna dimension selected depends to operation frequency. For 1 GHz dimension of antenna

L = 7.5 cm. For 5 GHz. dimension of antenna is L = 1.5 cm (λ\4 respect to the frequency).

Distance between elements(d) are λ\4, λ\2 and λ chosen for both frequencies.

Lineer and planar array structures analyzed for both frequncies, distance and antrenna dimensions. One dimension arrays designed on x or y plane, two dimension arrays designed on x-y plane.

For number of array elements(n) 3, 5 and 10 element number selected. Number 3 is selected because of cubesat dimensions. Proposed antenna can use for communication of cubesat to ground stations.Cubesat dimensions are 10x10x10 cm.3 cm (λ\2 for 5 GHz.) element distance on 3x3 array structure provides efficient use of cubesat area with antenna dimension of L = 1.5 cm.

In section 7.1 radiation patterns for 1 GHz frequency presented.

After section 7.1 radiation patterns for 5 GHz frequency presented in section 7.2.

After these radiation patterns comparasion the proposed antenna with quarter wavelength monopole is in section 7.3.

Last part of section 7 is antenna array feed network. A feed network is designed for 16 elements antenna array by using RF power divider.And details can found in section 7.4.

7.1 Frequency = 1 GHz

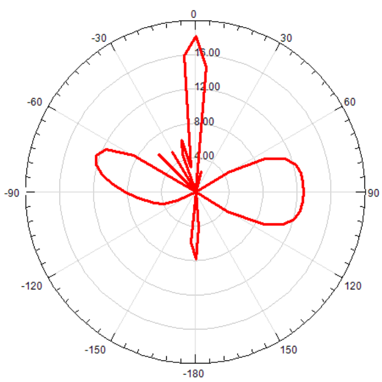

Figure 7.2 : 5x5 array d=λ phi=0˚

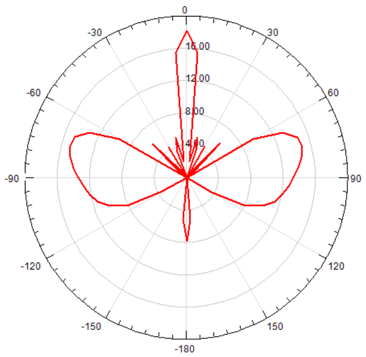

Figure 7.3 : 5x5 array d=λ phi=90˚

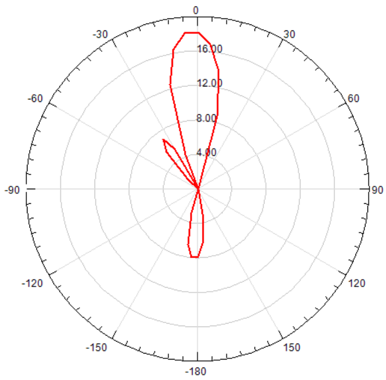

Figure 7.4 : 5x5 array d=λ\2 phi=0˚

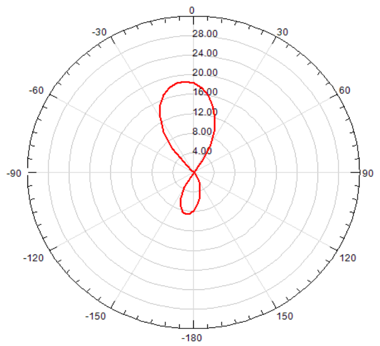

Figure 7.5 : 5x5 array d=λ\4 phi=0˚

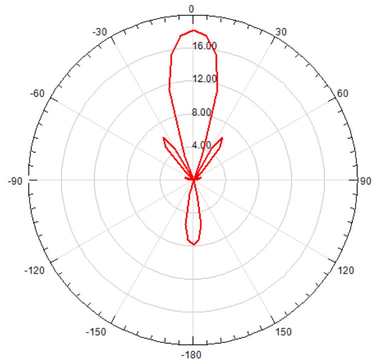

Figure 7.6 : 5x5 array d=λ\2 phi=90˚

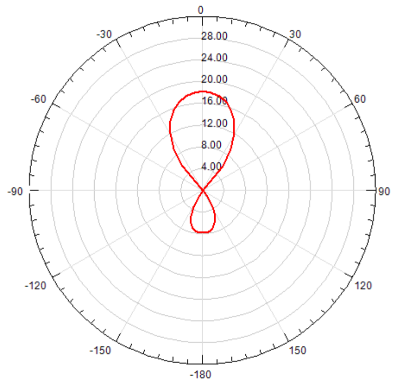

Figure 7.7 : 5x5 array d=λ\4 phi=90˚

7.2 Frequency = 5 GHz

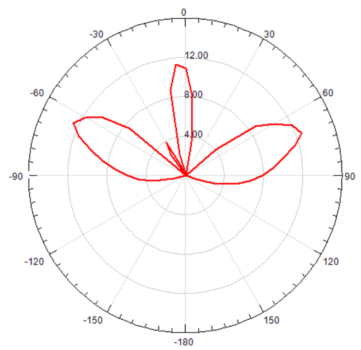

Figure 7.8 : 3x3 array d=λ phi=0˚

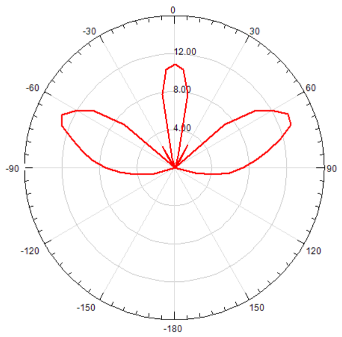

Figure 7.9 : 3x3 array d=λ phi=90˚

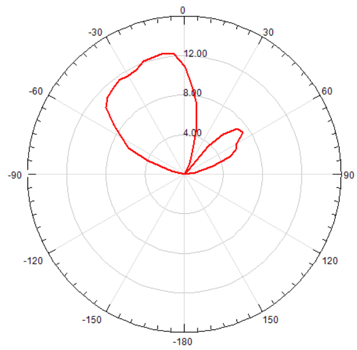

Figure 7.12 : 3x3 array d=λ\4 phi=0˚

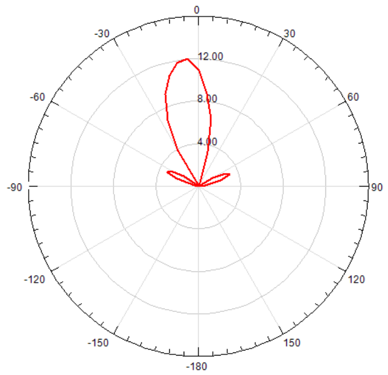

Figure 7.10 : 3x3 array d=λ\2 phi=0˚

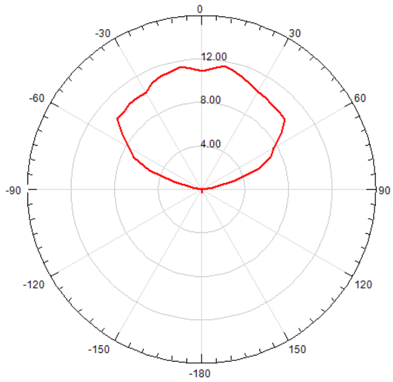

Figure 7.13 : 3x3 array d=λ\4 phi=90˚

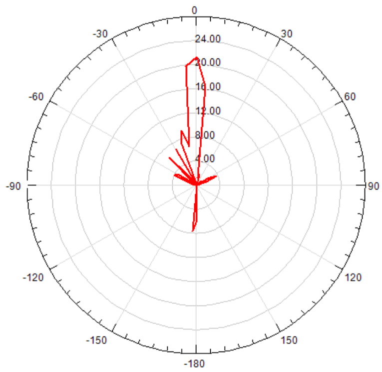

Figure 7.14 : 10x10 array d=λ\2 phi=0˚

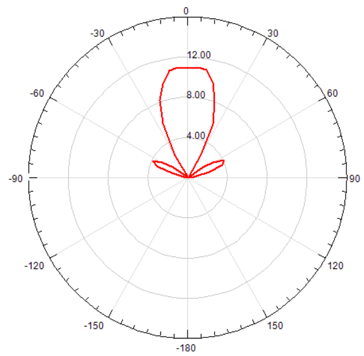

Figure 7.11 : 3x3 array d=λ\2 phi=90˚

As seen from radiation pattern Figures 7.2, 7.3, 7.8, 7.9 i elements is equal to wavelength, radiation pattern of antenn broadside and end-fire arrays.

For distance between elements is equal to quarter wave specific radiation pattern characteristic as sen in Figure 7.5, 7

For distance between elements is equal to half of waveleng of antenna is end-fire.One can see this feature in Figures 7 7.14, 7.15. Increasing number of elements cause to incre decrease side lobe level. As seen from Figure 7.11 HPBW

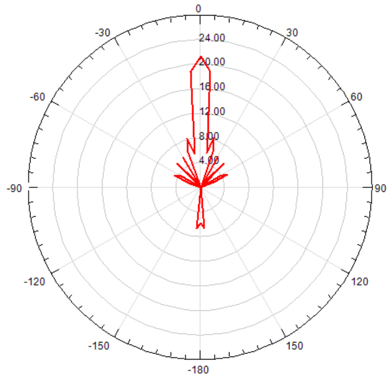

Figure 7.15 : 10x10 array d=λ\2 phi=90˚

7.3 Comparasion The Proposed Antenna With Quarter Wavelength Monopole

For compare in two antenna structure a quarter wavelength monopole antenna for 1 GHz designed in HFSS program.Below one can see single element antenna design and radiaton patterns for this structure.

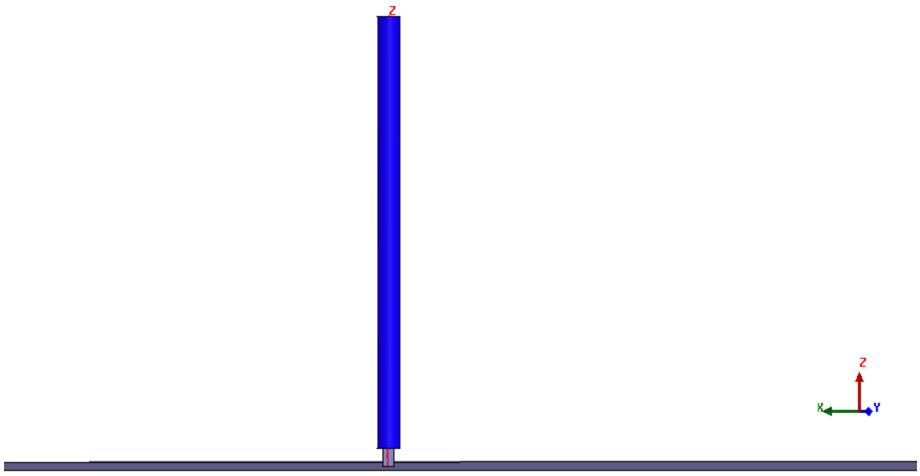

Figure 7.16 : Quarter wavelength monopole for 1 GHz (L = 7.5 cm)

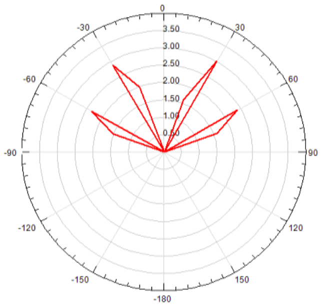

Figure 7.17 : 10x10 array d=λ\2
phi=0˚

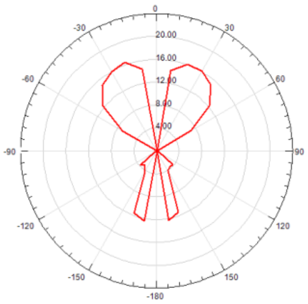

Figure 7.19 : 10x10 array d=λ\10
phi=0˚

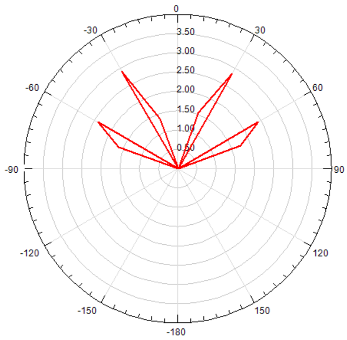

Figure 7.18 : 10x10 array d=λ\2
phi = 90˚

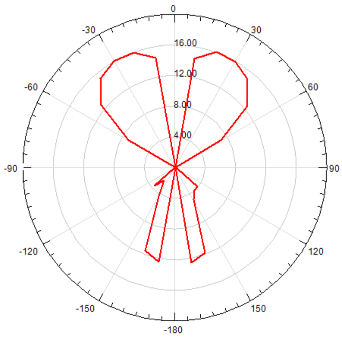

Figure 7.20 : 10x10 array d=λ\10
phi = 90˚

As seen from the figures for well directive and gain, distance between elements of quarter wavelength monopole antenna has to be less as λ\10 as seen in Figure 7.19 and 7.20. With same amount of quarter wavelength monopole and d = λ\2, gain just 3 dB as seen in Figure 7.17 and 7.18.

There is no radiation on z direction. This is a well-known characteristic of monopoles.
Compare with proposed antenna and quarter wavelength monopole; there is very important two difference can seen. With 100 antenna; quarter wavelength monopole has 16 dB gain with two main lobe. With same amount of proposed antenna 20 dB gain with one narrow main lobe. One can see this easily with comparing the Figures 7.19 and 7.15.

7.4 Antenna Array Feed Network

In this study a feed network is designed for 16 elements antenna array by using RF power divider. AWR MWO is used for simulations. Design is done on FR4 (h = 1.6mm, $\varepsilon_r = 4.4$, metal thickness = 35 μm).

Feed network impedance is lossless, 50 Ω and there is any external component for impedance matching. All system is designed with microstrip lines. 4x4 array's feed network design is simple. Also implementation of microstrip network is very easy. A power divider is designed for 16 antennas. Center frequency of the divider is 5.5 GHz and λ/4 transformers are used. Line impedances are 100 Ω, antenna impedances are 50 Ω and transformer impedances are 70.7 Ω. There is any length limit for 100 Ω lines but transformers' length is 1.74 mm.

After simulation divider system's S11 is nearly -30 dB and lower than -10 dB in antenna's operating band as seen in Figure 7.24. Also divider ratio is must be -12.04 dB in ideal, -12.08 dB is found at center and it is lower than -12.2 dB in band as seen in Figure 7.23. And feed system design can seen in Figure 7.21 and 7.22

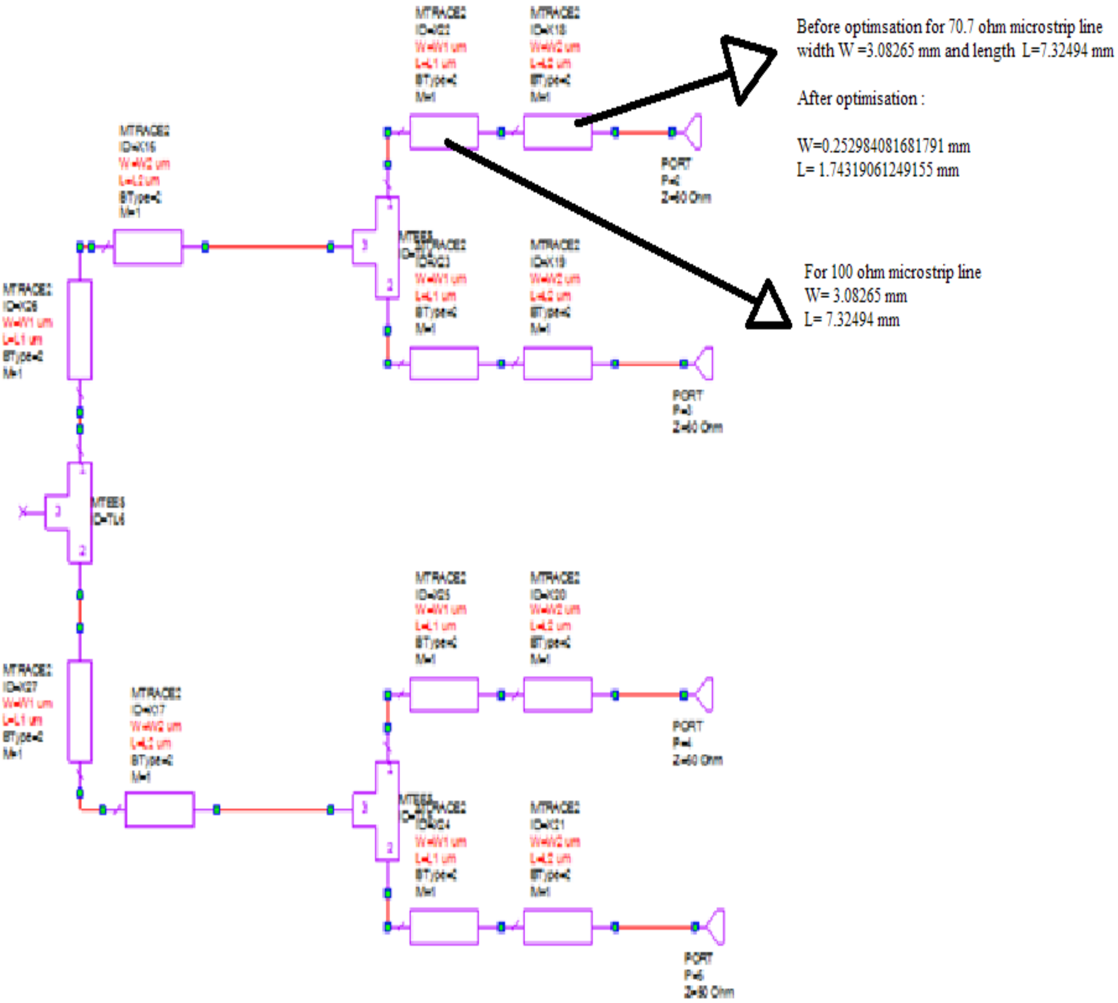

Figure 7.21 : Basic structure of 16 ways divider

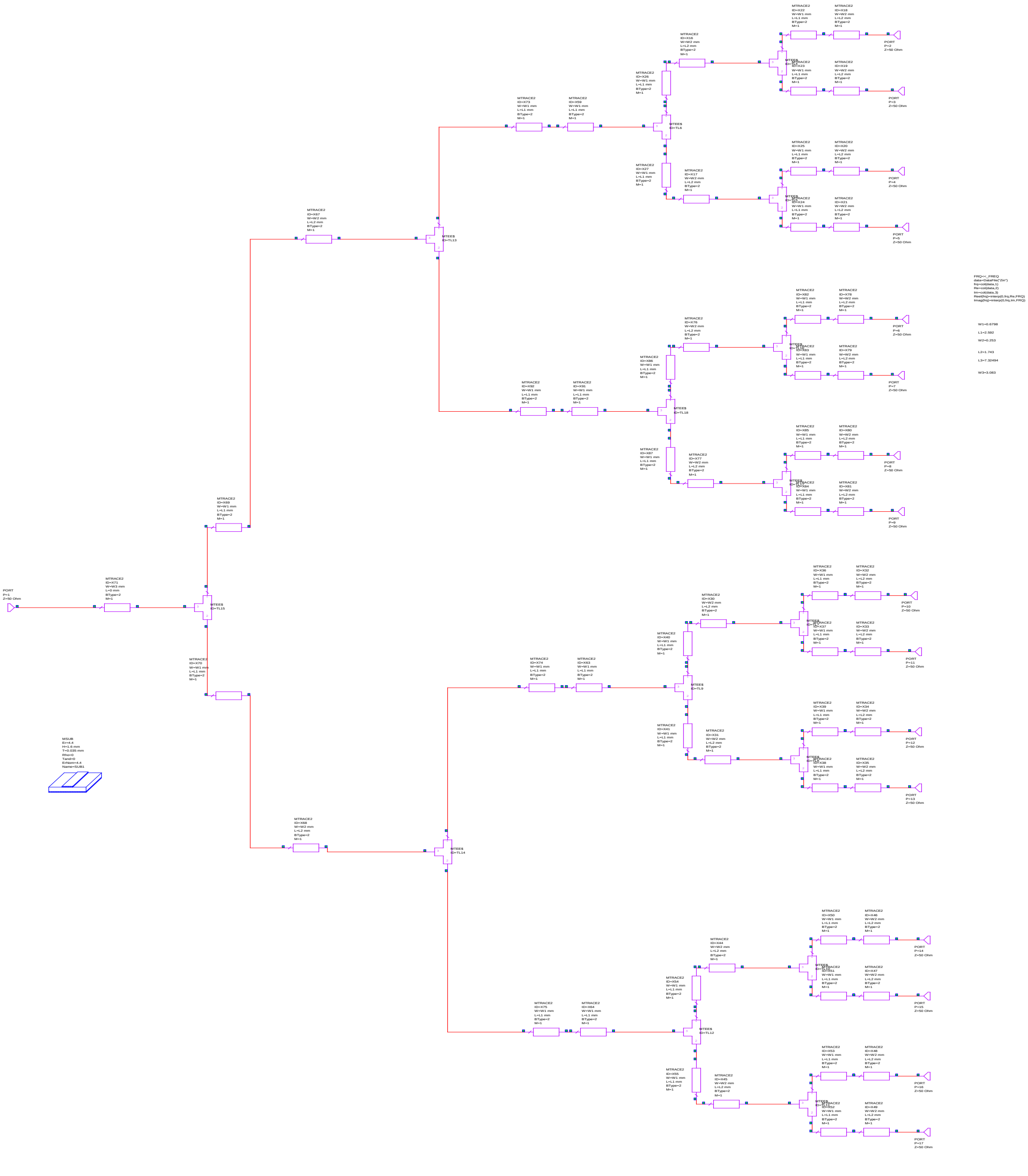

Figure 7.22 : Feed Network System for 16 Antennas (Designed on AWR WMO)

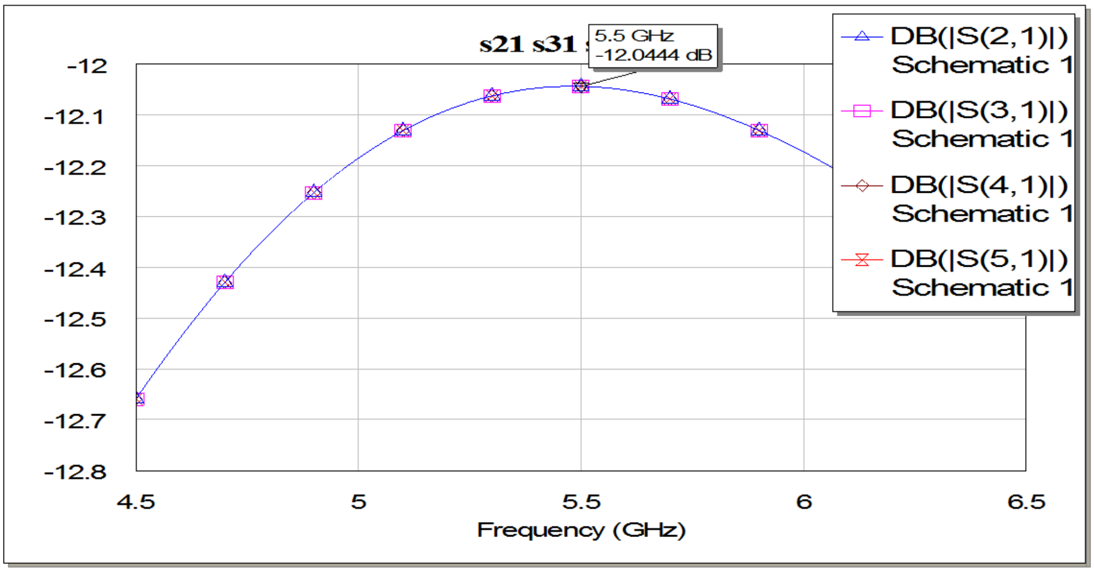

Figure 7.23 : Power ratio at output (antenna ports).

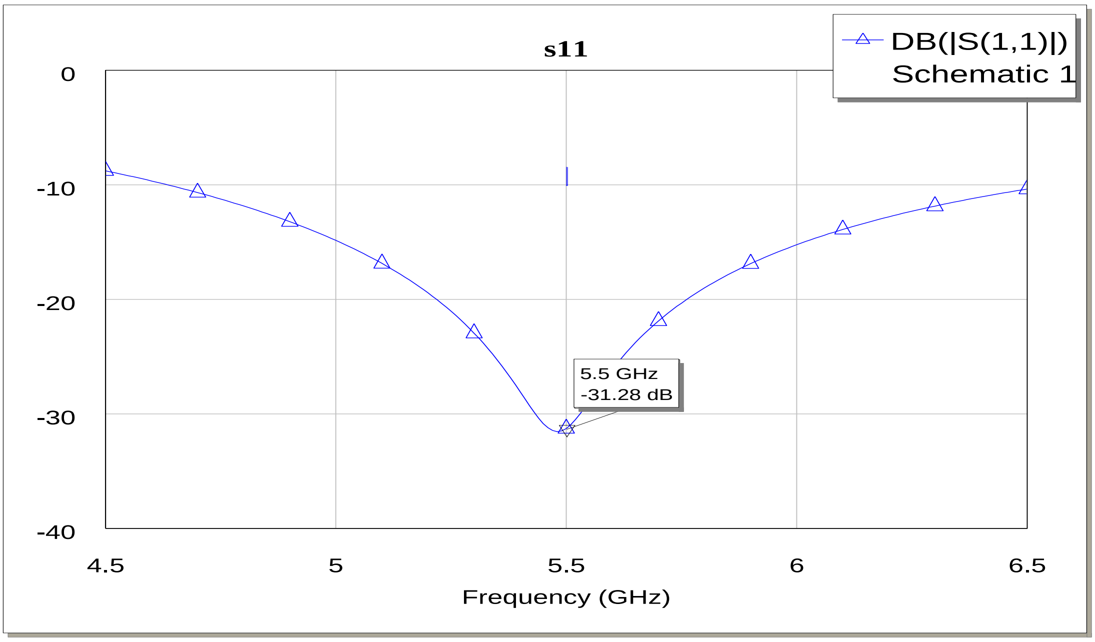

Figure 7.24 : Reflection at input port.

8. MAKING AN PROTOTYPE ANTENNA

Last part of this work; making an prototype antenna. For ground aluminum board selected with measure of 50x50 cm with thickness 2 mm. Antenna is handmade from 1 mm. radius copper wire. Radius is 1 mm because of hard to find bigger radius in the market. First antenna shape curled from wire and soldered. For placing antenna to ground, aluminum board drilled from middle point. To that point N-Type-Female-4 connector installed. Last step is soldering antenna to connector. And prototype is ready for testing. Prototype antenna can seen in Figure 8.1.And measure results seen in Figure 8.3.

Figure 8.1 : Prototype antenna with L ≈ 7.5 cm, radius = 1 mm

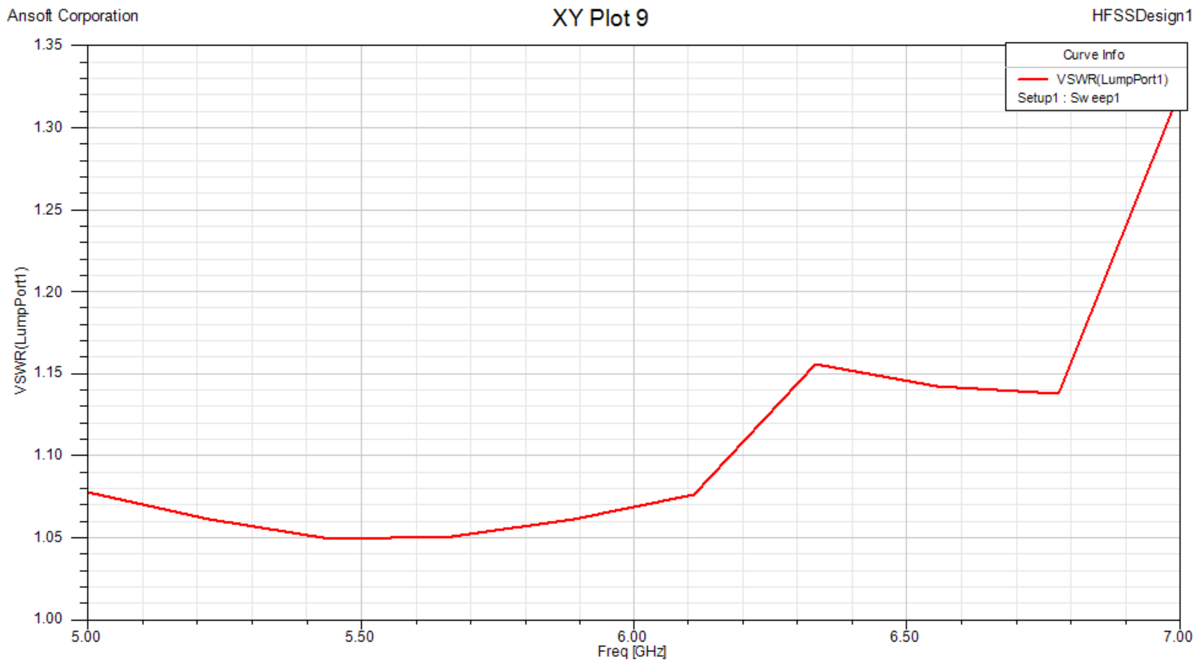

Figure 8.2 : VSWR with 4 mm radius, frequmcy 5 – 7 GHz

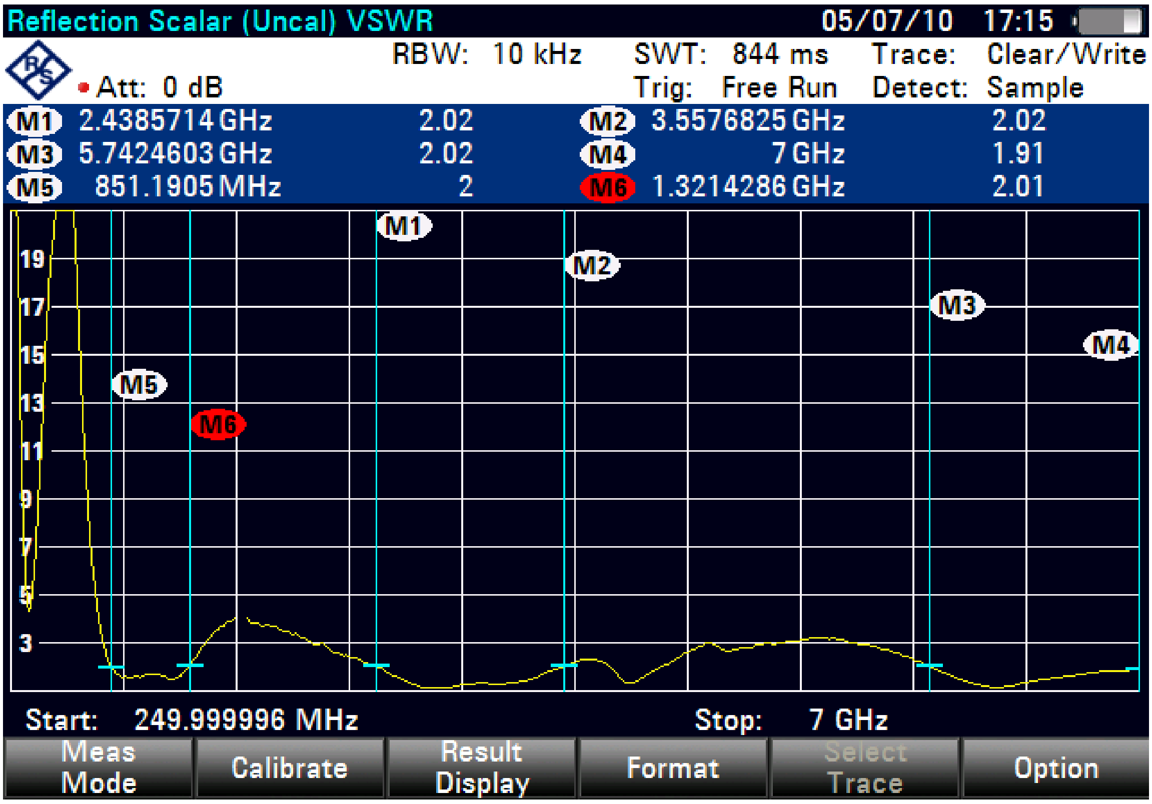

Figure 8.3 : VSWR Measurement results between 250 MHz – 7 GHz

As seen from Figure 8.3, prototype antenna has 3 band;

1) 851 Mhz. – 1.321 GHz. : Bandwith = 470 MHz.
2) 2.43 GHz. – 3.55 GHz. : Bandwith = 1120 MHz
3) 5.74 GHz. – 7 GHz. : Bandwith = 1260 MHz

As seen from Figure 8.2 simulation results shows antenna can use between 5 – 7 GHz.But measurement results shows for this band start from 5.7 GHz.

There is difference with prototype and proposed antenna.Thats because antenna wire radius (proposed radius 4 mm, prototype 1mm) and dimensions.Prototype antenna preferred length L = 7.5 cm. but its handmade and dimensions cant be exactly 7.5 cm.

And these are makes big differences.But still antenna has good performance with 3 band and 2850 Mhz. bandwith.

9. CONCLUSION

A wideband monopole antenna with G type structure has been analyzed fed by 50 Ω coaxial cable. Closed rectangular wire radius, open rectangular wire radius, length of wire respect to the frequency and angles of corners are analyzed for 1.1 GHz and 5 GHz. The software Ansoft HFSS is used for analyze parameters of antenna for gain, bandwith and radiation pattern. At first; rectangular radius analyzed from 2 mm to 6 mm, 4 mm radius gives best result for 0.90 GHz to 1.7 GHz with VSWR under 2 and totalgain about 6 dB.

For length of wire, most common used wavelength for monopole antennas are choosed; 0.05 λ, 0.25 λ, 0.5 λ, 0.75 λ and for multiple resonance 1 λ, 2 λ are choosed. Simulation proves for 1.1 GHz selection of length wire for 0.25 λ provides 800 MHz bandwith. For 5 GHz, length (L) = 1 λ is provides more than 1 GHz and VSWR less than 1.1.

For angles of corners initial value is 90˚. From square to parallelogram, difference seen at gain, bandwidth and radiation pattern. Changing angle causing coupling effects for 1.1 GHz and 5 GHz. Coupling effects makes narrow bandwith for 1.1 GHz.

For array analysis parameters are distance between elements (λ\2, λ\4, λ),number of elements (3, 5 , 10).These parameters analyzed for 1 GHz and 5 GHz.

For different operating frequency; different antenna dimensions used. For operation frequncy 1 GHz, dimension of antenna L = 7.5 cm, for 5 GHz. L = 1.5 cm.

One can see that from figures 7.4, 7.6, 7.10, 7.11 with distance between elements d = λ\2, proposed antenna can use in so many wireless applications.

For future works; antenna array can realize and radiation pattern can measure in an electromagnetic lab. After measurement of radiation pattern, results can comparing with simulation. If there is do much difference, reasons can research.If measurements and simulation values are near; an antenna array can build.

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CURRICULUM VITAE

Candidate's full name: Yasin Levent KURU

Place and date of birth: Elazığ - 1982

Universities and
Colleges attended:University of Istanbul – Industrial Engineering

Publications:

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